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HEAT AND INFANT MORTALITY.

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Read before the Pediatric Section of the American Association for Study and Prevention of Infant Mortality, Washington, D. C., November 14, 1913.

By far the most conspicuous phenomenon in connection with the mortality of infants is the well-known increase in the number of their deaths which takes place in the summer months. No incidence of death in any other age group seems to be so immediately determined by meteorological conditions.

Hot summers produce an abnormally high infant death rate and cool summers the reverse. For instance, Kruse (30) points out that the infant death rate in German cities of over 15,000 inhabitants decreased from 190 in 1901 to 153 in 1910, a cool year. Yet, the universally hot summer (in Europe) of 1911 was accompanied with a great rise in the infant mortality, so that the infant death rate in these cities for that year was 187, a rate not surpassed by any year subsequent to 1901.

Again, Liefman and Lindemann (38) state that the total number of infants dying in Berlin in July and August, 1910, was 1,439, while in the same months of 1911, 2,050 died, an excess of 611.

The relation of heat to the summer deaths of infants has naturally been the subject of much statistical inquiry. Forty years ago, no doubt existed, in this country at least, as to the direct effect of heat in causing increased infant mortality in the summer. The discoveries and developments in bacteriology and the etiology of infectious diseases, however, gradually displaced heat into the background as a direct factor in the deaths of infants during the summer time. Until a few years ago the general opinion has prevailed that, while summer heat stood in casual relation to summer deaths, this relation was by no means immediate. Heat was regarded as an agent calling other deleterious influences into action.

Recent observations, however, particularly those in Germany, of Finkelstein (9), Rietschel (54, 55, 56, 57), Liefman and Lindemann (37), Klose (28), Kathe (25), and others have reopened the question. We must now ask ourselves if summer heat is not, after all, by its direct action the determinant of a large part of the summer mortality of infants.

It is to be regretted that the recent careful studies which have been undertaken abroad have not been duplicated to any great extent in this country and that it has been necessary to derive most of the material for this paper from foreign sources.

It has naturally been found impossible, within the limits of this article, to give complete treatment to the subject, but an endeavor has been made to summarize the more important observations.

Relations of the Summer Mortality of Infants to the Temperature Curve.

In the past, numerous comparisons have been made and many charts published showing the relation of temperature to infant deaths. Owing to the great prevalence, in the summer, of deaths from intestinal diseases in babies, such curves have dealt mainly with the relation of temperature to deaths from this cause. Moreover, the mean temperatures for weekly or monthly periods have been the values taken with which to compare the infant deaths occurring in like periods.

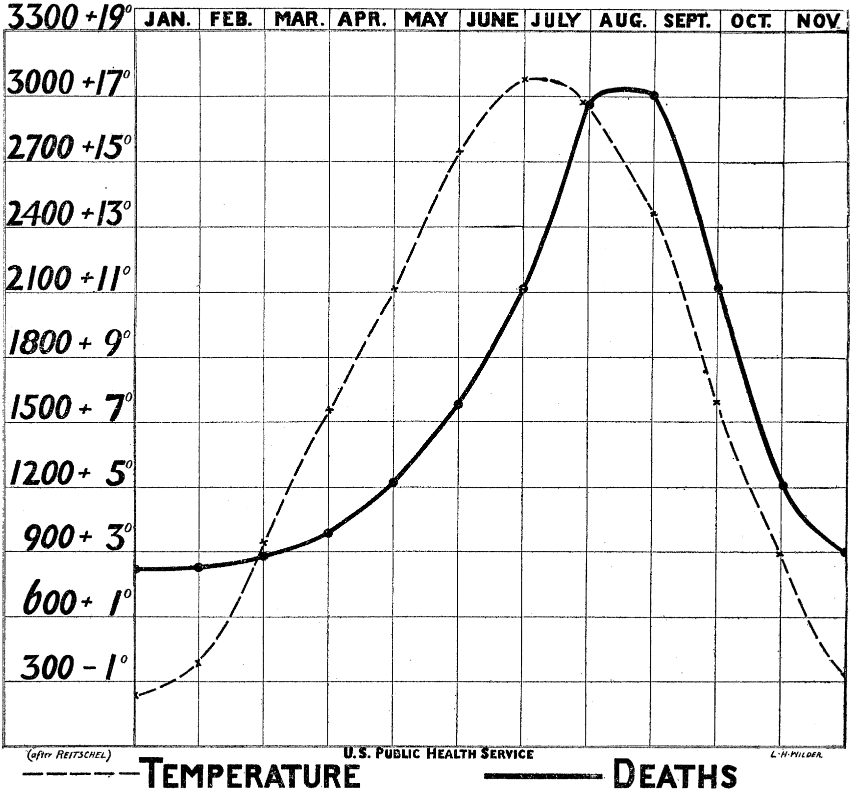
The resulting curves are of a type familiar to us all. As an example, let us look at Chart I from Fuerst (54). This chart shows the monthly deaths of infants from gastrointestinal diseases in Munich from 1895 to 1904, as compared with the mean monthly temperatures.

It will be seen that the death curve lags behind the temperature curve, rising steeply to its apex in August and declining at a later period than the temperature curve, to reach the winter norm in December.

It has been pointed out by Miller (43) in this country, as far back as 1879, that we can not make reliable deductions from comparisons of this character. If we wish to study the direct effect, if any, of heat upon infant mortality, we must compare the daily deaths with the daily temperatures. More recently this was pointed out by Prausnitz (52), Finkelstein (9), Willim (63), Liefmann and Lindemann (37), Schwarz (69), and others. Willim and Finkelstein seem to have been the first to publish such curves, but the most careful study of this nature in recent literature is that of Liefmann and Lindemann, which deals with the relations of heat to infant mortality in Berlin for a period of 15 years.

CHART I.

MONTHLY INFANT DEATHS FROM INTESTINAL DISEASES IN MUNICH, 1895–1904, COMPARED WITH MEAN MONTHLY TEMPERATURE



(after RIETSCHEL) U.S. PUBLIC HEALTH SERVICE L. H. HILDER.

Let us now examine one of Liefmann and Lindemann's[1] charts (Chart II), which shows the relation of the daily infant deaths to the daily temperatures in Berlin during the year 1905, which was characterized by some hot weather for that latitude.

According to these authors, in the spring of that year the daily infant deaths were between 15 and 20. Had this rate been kept up throughout the year, some 7,000 babies would have died. As a matter of fact, there were about 10,000 deaths of infants, the excess being almost entirely due to increased mortality in the summer. On certain days the mortality was so high that it was two or three times the norm.

An examination of this chart shows two striking peculiarities. First, two sharp prominences with their apices on the 7th of June

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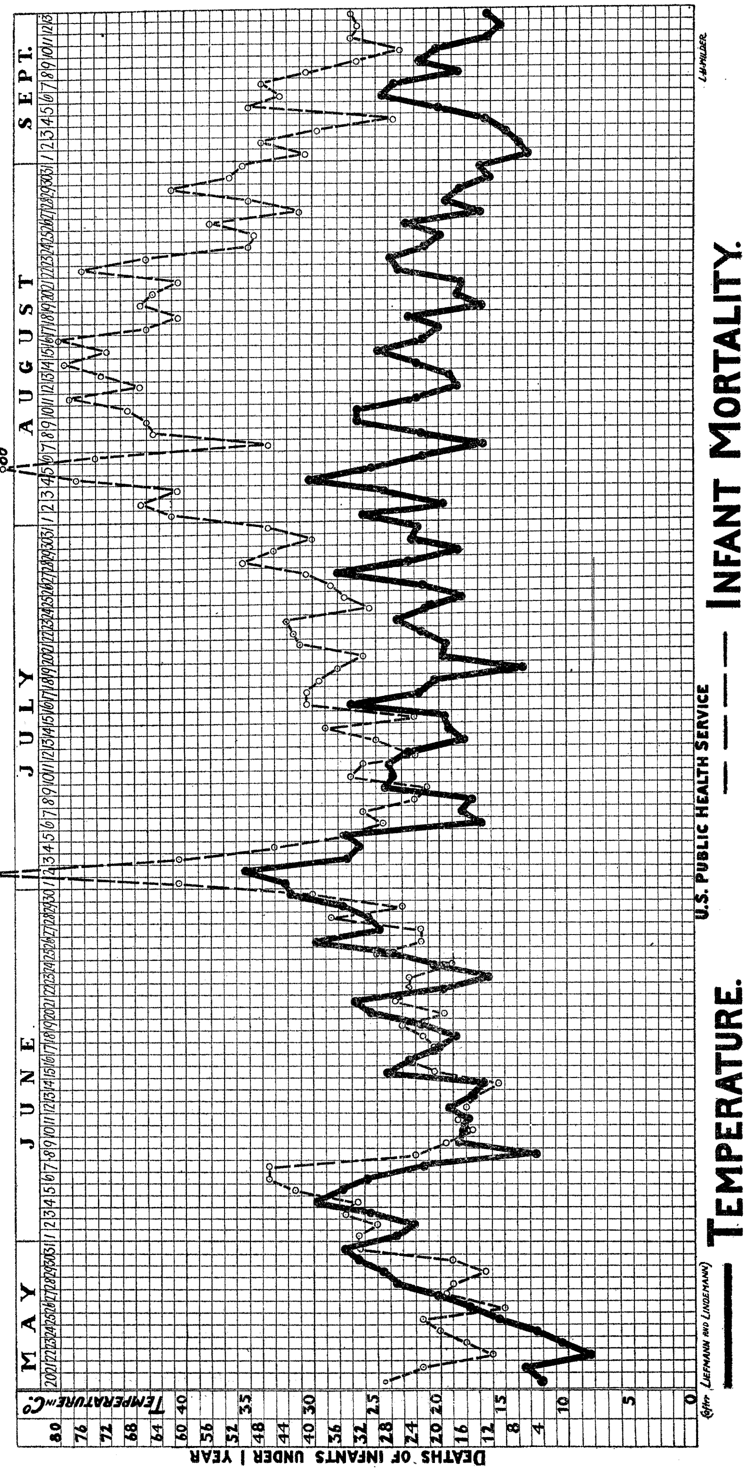
[1] A careful study of their work is recommended, as well as of Rietschel's comprehensive monograph on this subject. I am indebted to these authors for much of my material.

CHART III.

BERLIN, 1905.—DAILY DEATHS OF CHILDREN UNDER 1 YEAR COMPARED WITH THE DAILY TEMPERATURE AT 2 P.M.



and the 2d of July, respectively, and, second, a high and broad elevation in August, crowned with a succession of smaller secondary prominences.

Liefmann and Lindemann distinguish two elements in their curves, (*a*) the early summer mortality, and (*b*) the late summer mortality.

Early summer mortality.—On inspection it is seen that there is a striking parallelism between the temperature curve and the mortality. This is especially manifest in the sharp increase in the number of deaths on June 30 and July 1, accompanying the high temperature on those dates.

This parallelism is manifest, not only on the hottest days, but the moderate heat of the 4th and 5th of June, also, is sufficient to provoke an increase in the deaths recorded.

An interesting circumstance, developed from the study of this and other curves in their series, is that, generally speaking, only temperatures of considerable height (22° to 25° C.) are effective in producing an increase in infant deaths. Often the first hot wave does not call forth the expected response.

The late summer mortality.—The late summer mortality corresponds to the high and broad curve of deaths from the middle of or end of July to the last of September. This portion of the chart presents a different relation to temperature than that corresponding to the early summer. The high mortality present in the first part of August no longer recedes to the norm with falling temperatures. On the contrary it remains great in spite of the interpolation of periods of cool weather of some duration. Nevertheless, rises in the temperature are accompanied by an increase in the number of deaths, which serves to give this curve its jagged outline.

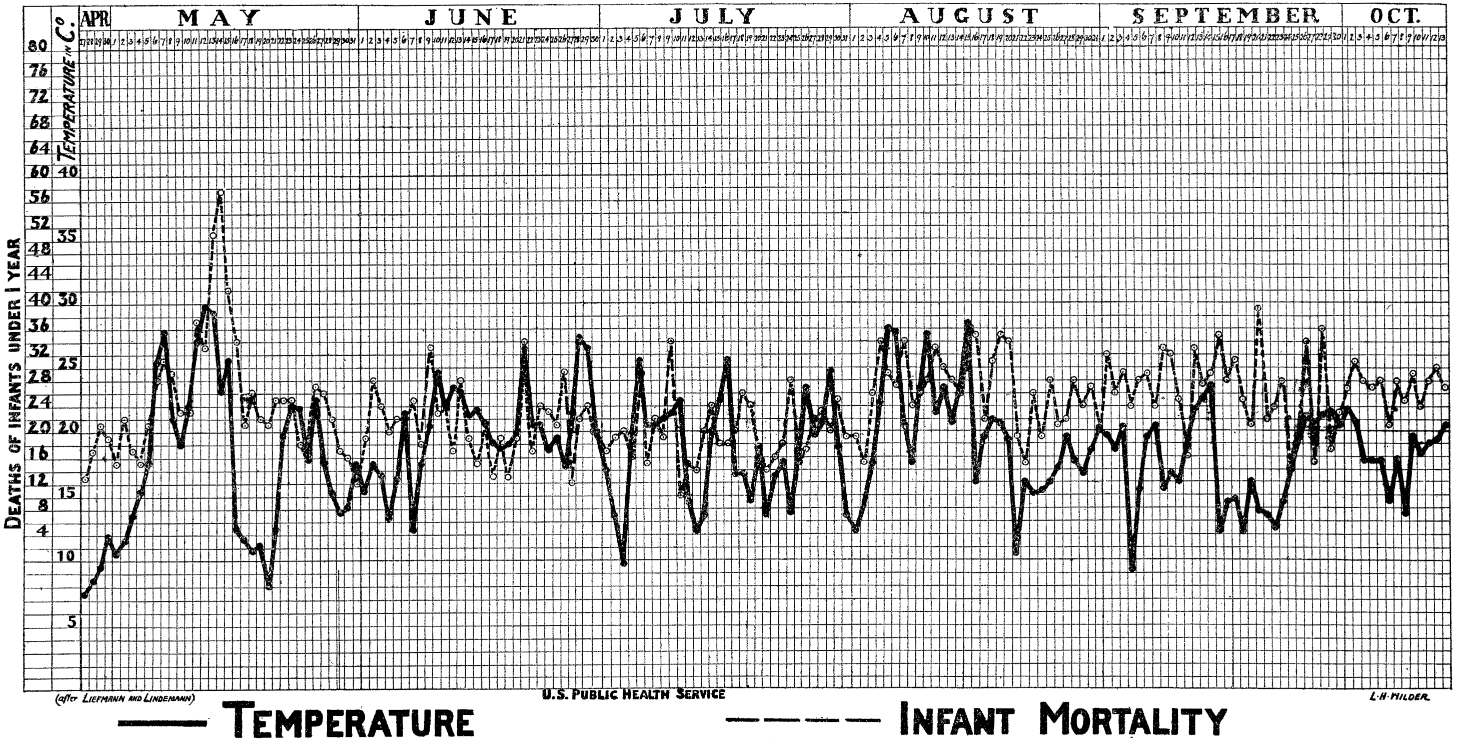
The mortality curve in this portion of the summer seems to express the summation of the effects of a long period of warm weather, as a basis, combined with the exacerbations provoked by repeated sudden increases in the temperature.

Curves of a cool year.—If now we examine these curves for a cool year, we find a different set of relations. Chart III shows these conditions during the year 1907, a cool summer with only one hot period in May.

We see, upon examination, a response to the hot weather of the 7th and 12th of May, but, owing to the very moderate temperatures prevailing throughout the rest of the year, the broad midsummer rise in the mortality curve is practically absent.

CHART III.

BERLIN, 1907.—DAILY DEATHS OF CHILDREN UNDER I YEAR COMPARED WITH THE DAILY TEMPERATURE AT 2 P.M.



(after Liefmann and Lindemann)

U.S. PUBLIC HEALTH SERVICE

L. H. HILDER.

Character of Deaths in the Early and Late Summer.

The differences in the reaction of the mortality curve to temperature in the early and the late summer is accompanied by differences in the nature of the infant deaths recorded. According to Liefmann and Lindemann, an examination of the death certificates showed that in the early summer a large number of deaths were recorded with acute symptoms not referable to the intestinal tract.

For instance, of the 88 infants dying on the hot day of July 2, 1905, only 16 died of intestinal diseases, while in 52, or about 60 per cent, the cause of death was given as convulsions, brain stroke, and heart failure, or, in other words, with symptoms mainly referable to the central nervous system.

As the summer progressed, however, the number of deaths from gastro-intestinal diseases gradually increased, so that toward the end of August and the beginning of September from 72 to 78 per cent of the diagnoses on the death certificates gave this class of diseases as the cause of death. Hot days brought an increased number of certificates recording deaths with acute symptoms, and a number of such deaths were found even in comparatively cool weather at this period.

A considerable difference in the duration of illness was apparent. In the early part of the summer about 50 per cent of the infants died after an illness lasting only one or two days, while in the latter part only about 20 per cent died with such acute symptoms. The remainder succumbed to illness of a more chronic character.

The following tables from Liefmann and Lindemann give a good idea of the relative frequency of deaths with acute symptoms and from gastro-intestinal diseases in the various parts of the summer (Table 1) and the course of the mortality from gastrointestinal diseases during the summer of 1905 in Berlin. (Table 2.)

TABLE 1.—*Causes of mortality during different parts of the summer, Berlin, 1905 (after Liefmann and Lindemann).*

	Number of infants dying each day—		
	In the cool part of early summer.	In the hot part of early summer.	In the cool part of late summer with high mortality.
Gastrointestinal diseases	3.0	13.2	41.3
Congenital debility and atrophy	6.0	6.2	4.3
Other affections	12.6	43.7	25.3
	21.6	63.1	70.9
"Other affections" above include convulsions, brain stroke, and heart failure	7.7	32.7	20

TABLE 2.—*Weekly deaths from gastrointestinal diseases in Berlin during the summer of 1905 (after Liefmann and Lindemann).*

	Total infant deaths.	Deaths from gastro-intestinal diseases.	
		Number.	Per cent.
Cool part of early summer (May 14–20)	171	25	14.5
Hot part of early summer (June 4–10)	228	66	29
Cool part of early summer (June 11–17)	125	41	33
Hot part of early summer (July 2–8)	315	148	47
Hot part of late summer (July 30–Aug. 5)	441	306	69
Cool part of late summer (Aug. 13–20)	498	389	79
Cool part of late summer (Aug. 27–Sept. 2)	347	250	72
Cool part of year after decrease in mortality (Oct. 1–7)	168	67	39

We see from the foregoing that the march of infant mortality in the first part of the summer is characterized by the great number of deaths with acute symptoms and short duration (24 to 48 hours), while later the high, broad, and slowly descending curve is largely produced by the deaths of infants who succumb to more or less subacute affections, mainly of the gastro intestinal tract.

The influence of heat upon the mortality of infants in the first part of the summer is apparently immediate. In the latter part of the summer this no longer seems to be the case. At first sight one would be inclined to state that, while some causal relation is manifest, the late summer mortality of infants is not directly influenced by the heat, which, therefore, can stand in no immediate relation to this phenomenon.

A closer examination, however, shows that we can, by no means, suppose that infants are necessarily relieved from the action of heat by reason of comparatively long remissions of the temperature in the latter part of the summer. If we are to examine the effects of heat upon infants, we can not arrive at conclusions by considering outdoor temperatures only. The nursling passes most of his time indoors, and it is the indoor meteorological conditions to which he is mainly subjected.

Indoor Temperatures.

The credit of calling attention to the importance of indoor temperatures belongs to Flügge (11), who, in 1879, published a series of observations upon indoor temperatures in midsummer. He found that the temperature indoors was dependent upon the degree of heat received by the walls from the sun.

The diffusion of the heat through the walls was found to be relatively slow, so that their inner surfaces reached their maximum temperatures in the following order: East wall, 9 p m.; south wall, 12 m.; west wall, 3 a. m.

The effect of the radiation of heat from the inner surfaces of walls, protracted far into the night, was to maintain the indoor temperature at a level considerably in excess of that of the external air. During a relatively cool summer Flügge found that the mean indoor temperature might exceed the exterior by as much as 9.5° C. (17.1° F.).

Other observations on the indoor temperature have been made by Meinert (41, 42), Hammerl (16), and Rietschel (55), in Germany; in this country by Chapin (4), Knox (29), and Helmholz, (19).

Meinert (41, 42) observed an average excess of 8.8° C. (16° F.) of the indoor over the outdoor temperature in a room in Dresden in which an infant had died of summer diarrhea.

Hammerl (16) made observations in the dwellings of workmen and found that the average mean indoor temperatures were greatly in excess of the outdoor. In one instance the temperature never fell below 24° C. (75.2° F.) for a period of over 14 days and often rose to 32° C. (89.6° F.), and, on one occasion, to 35° C. (95° F.) with outdoor temperatures that never exceeded a maximum of 23.7° C. (74.6° F.).

In the cool summer of 1910 Rietschel (55) made observations with maximum and minimum thermometers and recording thermographs in dwellings in Dresden, in which, for the past 5 years, a high infant mortality had been recorded.

He states:

> I admit frankly that the results astonished me. I had indeed supposed that in such dwellings temperatures of considerable height might prevail in summer, but I had never expected that such excessive temperatures could be maintained, not only daily but weekly, with an outdoor temperature relatively so low.

In some instances the temperature rose to 35° C. (95° F.) and 37° C. (98.6° F.), with outdoor maximums of but 23.5° C. and 21° C. (74.3° F. and 69.8° F.). During the hot summer of 1911 he reports an instance in the home of a workman of maximum temperatures of 38° C. (100.4° F.) with a minimum of 30°C. (86° F.).

Similar measurements have been made in this country by Chapin (4), Knox (29), and Helmholz (19) during the summer of 1912 with like results. Helmholz observed, in the stockyards district of Chicago, maximum indoor temperatures 30° F. in excess of the outdoor maximum. Minimum temperatures below 80° F. were rather infrequent, occurring only 83 times out of 1,374 maximum and minimum readings.

It is clear, from the foregoing, that infants are often obliged to endure, for considerable periods, temperatures which are greatly in excess of those of the external air. Moreover, the effect of these temperatures is often enhanced by excessive clothing and rubber diapers. It is a too frequent experience to find, in crowded tenement homes, the busy mother keeping the baby in the kitchen, often near the stove, in order to have it close at hand.

Effects of Humidity.

The influence of a high degree of moisture in the air in increasing the effects of heat is well known. It would naturally be expected that hot days with high humidity would show the greatest increase in infant deaths. The observations on this point are inconclusive. Days on which great infant mortality has been recorded have, for the most part, been hot and dry.

Meinert (41), Prausnitz, Liefmann and Lindemann (37), and others point out that the relative humidity of the external air is by no means an index of the moisture to which infants are exposed. In the dwellings of the poor, where the great majority of infant deaths take place, the infant passes a large part of his time in narrow and usually crowded quarters, where the relative humidity may be greatly raised by the lack of ventilation, the moisture derived from the breath and skin of numerous inmates (frequently 5 or 6 in a single room), and the water evaporated in cooking, ironing, and washing.

Indeed, Kubly's (31) observation (cited by Meinert) showed that in the dwellings of the poor in Dorpat a mean relative humidity of 83 per cent was found in 223 observations and in 30 instances 90 to 98 per cent was recorded. Knox's (29) observations in Baltimore during the summer of 1912 showed the relative humidity in such dwellings to vary between 70 and 80 per cent.

Circulation of Air.

It is evident that circulation of the air is of great assistance in eliminating heat from the body by accelerating evaporation. I will cite only the recent experiments of Flügge and his coworkers, Paul, Ercklentz, and Heymann (13). They showed that in stagnant air symptoms of heat retention begin to make their appearance at temperatures of 24 to 25° C. (75.2° F. to 77° F.), which, however, disappeared when the air was set into motion by a fan.

If, then, heat is to be regarded as a direct factor in the causation of summer infant mortality, we would expect to find an increased number of deaths of infants in houses and in sections of cities where conditions are unfavorable to the circulation of air. Such, we find, is the case.

Ballard (1) in his extensive investigations of summer mortality in England noted that when the wind had free access to houses the summer infant mortality was low, while it was high in those cities, or sections of cities, where, from the disposition of the streets or houses, they could not be swept by the prevailing winds in summer.

Meinert (41), to whom belongs the credit of being the first to investigate in Dresden the relation of housing conditions to the summer mortality of infants, found that in practically every instance in the case of 580 infants dying in the 11 summer weeks of 1886. the conditions were such as to prevent the free circulation of air in the rooms in which these children lived. In only one instance did any of these infants die in a house exposed freely on all sides to the wind. The infants died in those dwellings which, from their low-lying situation, their location in the rear of other dwellings, the presence of courts, narrow streets, and shut-in style of architecture, were denied the access of cooling breezes or, in which from the disposition of the windows, through ventilation was impossible.

Thus on low-lying Hechtstrasse, with shut-in houses and many courts, 18.49 per cent of the living children under 1 year died; on high-lying Kiefernstrasse, with a more open style of architecture, only 2½ per cent; upon Johan Meyer Strasse, with model workmen's homes, open to the air on all sides, none.

Prausnitz (52) points out that in the absence of through ventilation the only exchanges which can take place between the inside and the outside air arise through differences in their temperatures.

In the absence of through ventilation these differences of temperature are so slight, in hot weather, that stagnation readily takes place. He and his coworkers investigated in Graz the location of windows in dwellings in which infants had died of summer diarrhea during the years 1903 and 1904. A dwelling was regarded as susceptible of through ventilation when it possessed windows in opposite walls, as partially so when the windows were in walls at right angles to each other, and as not susceptible when windows in one wall only were found.

They obtained the following results:

Year.	Susceptible of through ventilation.	Partially susceptible of through ventilation.	Not susceptible of through ventilation.
	Per cent.	*Per cent.*	*Per cent.*
1903, 1904	15.4	19.5	65

It will be seen from the above that approximately 80 per cent of these dwellings did not present conditions favorable to a free circulation of air.

Other Housing Conditions.

Besides Meinert's former work other careful studies of housing conditions in relation to housing have been made. Among these may be especially mentioned those of Willim (63) in Breslau, of Liefmann (34), and of Kathe (25) in Halle, and of Liefmann and Lindemann in Berlin. These investigations all bear testimony to the great influence housing conditions have upon infant mortality, and particularly the conditions favoring high indoor temperatures or the absence of free circulation of air.

While it is true that the conditions were often such as would also favor the dissemination of infectious disease, we encounter the paradox that certain conditions, intrinsically unhygienic, have a distinctly favorable influence on the summer mortality of infants.

Thus it was found by Meinert, Willim, and Liefmann and Lindemann that infants living in basements and cellars show a smaller increase in their summer death rates than do breast-fed infants; while, with respect to the other stories, the death rate usually increases as we go up, being found highest next to the roof. (Meinert found the greatest number of deaths in the ground and first floors.)

Liefmann's and Kathe's investigations in Halle showed that the summer mortality of infants was rife, not only in certain streets, but in certain houses. Thus Liefmann found that out of 380 streets which Halle possessed at that time, no less than 141, or over 37 per cent, had no infant deaths.

We can also readily conceive from the character and situation of the houses in which infants die that, once they are heated through by the warmth of the early summer, the heat stored in the earth, pavements, and walls, in their shut-in location, prevents any substantial cooling off in the late summer, in spite of periods of moderately cool weather. In the early summer, before there is much stored heat, remissions in the external temperature have a much greater effect.

Effects of Heat in Causing Death.

It must be clear from the foregoing that the greater the summer heat the greater the number of deaths and that it is an indoor and not an outdoor climate to which infants are exposed. There remains for discussion the manner in which their deaths ensue. There are two hypotheses by which these are usually explained:

I. Owing to the fact that the great majority of infants dying in the summer are bottle-fed, the deduction is logical that the onus of their deaths must be placed largely upon the food most generally used in the artificial feeding of infants, namely, cows' milk, which becomes so readily spoiled by the summer heat when carelessly produced and handled.

We find two views generally held to explain the pernicious action of cow's milk in the summer:

1. That as a result of careless handling and inadequate cooling on the part of the producer and the consumer, the germs which always contaminate cow's milk undergo such proliferation that the ordinary saprophytic bacteria in milk or their toxic products endanger the life of the artificially fed infant.

2. That the deaths of artificially fed infants are not due solely to the use of a germ-laden milk and its resulting poisons, but that the use of an alien food creates a predisposition to infection with pathogenic bacteria which may be acquired in other ways than through the milk—as, for example, through contact or by the agency of flies.

II. A second hypothesis, held in this country some 35 years ago, and advanced anew by Meinert in 1881, is that heat itself, by its various effects upon the infant organism, must be regarded as the chief factor in the summer mortality of infants. This theory has recently gained many adherents abroad, such as Rietschel, Finkelstein, Liefmann and Lindemann, Kathe, Klose, Prausnitz, and others.

I will endeavor to discuss, as briefly as possible, these hypotheses.

Effects of stale or germ-laden milk.—Milk is so plentifully seeded, during the course of its production and handling, with germs of all kinds, their multiplication is so favored by temperatures in excess of 60° F., and the possibilities of transmitting disease through its use are so obvious that none can deny its agency in this respect. Indeed, the accumulating literature of the epidemics of typhoid fever, the paratyphoid affections, diphtheria, scarlet fever, and septic sore throat transmitted through the agency of milk, not to mention the frequent presence of the tubercle bacillus in milk and milk products, only serve to emphasize the necessity of rigidly controlling the production and handling of this great source of food.

The most extensive investigation of recent years as to the effects of feeding different kinds of milk to infants is that of Park and Holt (49) in New York. Six groups of infants were observed, respectively fed on cheap store milk, condensed milk, milk from a central distributing station, good bottled milk, the best bottled milk, and breast milk.

During the winter but little differences in the results were noted, no matter what milk was fed. During the summer, however, the differences were striking. The infants fed on breast milk and the best bottled milk showed the best results, while these were very bad in the case of the infants fed on the condensed milk and the cheap store milk.

Rietschel, Liefmann and Lindemann, and others, however, advance the following reasons to show that the influence of cow's milk in causing summer infant mortality has been overestimated:

1. The hypothesis that the ordinary saprophytic germs of milk produce disease and death in infants is singularly lacking in experimental confirmation. The most exhaustive and complete experiments of this kind, i. e., those of Flügge (12), show that, at most, only the peptonizing bacteria in milk may have some harmful action

and are capable of exciting diarrhea when fed to dogs in large quantities.

2. Milk epidemics reported, in the literature, are mass epidemics, like other food epidemics. All the individuals, irrespective of age, who took the milk were affected. The course of these epidemics has also been quite different from that of the summer diarrhea of infants.

3. The use of sterilized milk ought to have a very great influence in reducing summer infant mortality. This does not seem to be the case. For instance, Liefmann (34) reports that infants boarded out in Halle have been provided since 1904 with sterilized milk by the municipality, yet the summer mortality among them from gastrointestinal diseases has been the same or somewhat greater than that prevailing for the rest of the city infants. Out of 384 infants supplied in this way during 1905, 1906, and 1907, 45, or about 12 per cent, died, of which number 30, or 8 per cent, died of intestinal diseases. Moreover, it has been a common clinical experience to see infants who have received nothing but the purest cow's milk, from a bacteriological standpoint, sicken with all the symptoms of typical summer diarrhea.

4. The increase in the summer mortality of infants seems to be initiated only by temperatures in excess of 24° C. While it is true that multiplication of germs in milk is greater at 30° C. than 24° C. it can not really be maintained that milk will not spoil almost as effectively at the latter temperature as at the former. Yet why should milk, spoiled at 24° C., not increase mortality, while milk spoiled at 30° does?

5. Finkelstein and Liefmann and Lindemann point out that on hot days a large part of the mortality ensues within 24 to 48 hours. Liefmann and Lindemann state, in this connection:

> It is difficult to conceive how the spoiling of the milk, the infection or the intoxication of the child, the sickening, and, finally, the death can be compressed all within a single day.

While it is true, in the case of the investigation of Park and Holt, that the infants who received the cheap store milk showed the worst feeding results there are certain circumstances, noted by the investigators, which must be taken into account in weighing the conclusions.

For instance, the results of feeding with condensed milk, in which the bacteria were found to be relatively few, gave results but very little better than those obtained with the cheap store milk. Again, we are told that the store milk was boiled and subsequently kept on ice in the majority of instances. The results of the laboratory examination of numerous strains of bacteria isolated from the milk showed only one or two strains that produced diarrhea when fed to kittens.

The environment of the children was not the same, those using the store milk belonging to a poorer and needier class. It is just this class of the population who crowd into the smaller tenement quarters with windows opening on courtyards and light wells.

Moreover, the investigators themselves state:

> There seem to be many factors, but a consideration of the facts accumulated indicates that heat is the primary factor, and bacteria and their products a secondary one except when the contamination is extreme or the pathogenic organisms present.

And again:

> The depressing effects of great atmospheric heat, i. e., a temperature of 90° F. or over, were very marked in all infants, no matter what their food. Those who were ill were almost invariably made worse and many who were previously well became ill.

They also indicate that proper care was, after all, the most important factor in keeping the infants well. With proper care some infants were fed successfully all summer on the cheap store milk.

That stale milk is not always deleterious to infants when the environment and care are good is shown by Rietschel's (57) experiments. Rietschel, after experimenting upon himself, fed to a series of infants cheap store milk which had previously been heated (as is the universal custom in Germany) and then allowed to stand in an open vessel for 24 hours at room temperature in the summer. The infants for the most part did very well on this diet and showed not the slightest trace of disturbance. In a few instances he had the impression that such a milk could cause more readily loose stools than a milk poor in bacteria. The milk was often turned when fed to the infants.

One further point which must be noted is that the infants which show the least increase in their death rate in summer are not the breast-fed infants, but infants who live in basements and cellars. Thus, Liefmann and Lindemann (37) inform us that in the cool part of the early summer in Berlin breast-fed infants died at the rate of 1.5 per day while in the hot part of the summer the rate was 4.5. The cellar infants died at the rate of 0.9 per day in cool weather and 2.25 per day in hot weather. Thus the death rate of the breast-fed children was increased threefold by the hot weather while that of the basement infants was only 2½ times as great. This can only be explained by reason of the greater coolness of cellars and basements.

Again, in the hot month of August in 1911 in Berlin, the breast-fed infants showed twice the mortality they did in the cool part of the summer, 107 dying in August, as against 51 in June.

While it can not be denied that milk, so long as it is exposed to contamination by human hands and flies, or is obtained from cows with inflammatory diseases of udder or with tuberculosis, must ever be liable to convey pathogenic germs, it would seem in view of the above statements that those who would attribute the bulk of the summer mortality of infants to stale milk take a too one-sided view of the matter and one not borne out by the facts.

The rôle of infections in the summer mortality of infants.—The summer diarrhea of infants has presented so many of the appearances, at first sight, of a specific infectious disease, as for example, its restriction to certain streets or sections of a city and the almost explosive rise of the mortality, that much labor has been expended to discover a specific organism.

The bacteriology of summer diarrhea was first carefully studied by Escherich (8) in Europe and Booker (3) in this country. They found no definite organism associated with summer diarrhea. In 1902 and 1903 Flexner (10), Holt, Duval, and Basset (18), Wollstein (67), Gary and Stanton, Wate (62), Kendall (26), and others reported the finding of the bacillus dysenteriæ (Flexner type) in the stools of numerous infants suffering from diarrhea. It should be noted, however, that in the great majority of those cases the dejections were typically dysenteric with blood and mucus in the stools.

Within the last few years Morgan (44, 45) and his coworkers report the isolation of a motile glucose-fermenting organism, which does not attack lactose or mannit from the stools of infants suffering from diarrhea in London during the years 1904–1906. The organism was present in about 45 per cent of the cases examined and produced diarrhea when fed to laboratory animals.

There is therefore evidence that a fair proportion of the deaths of children in summer are due to specific infections, but the evidence adduced is not sufficient to explain all of them in this way. Moreover, Liefmann and Lindemann (37) have studied the course of other epidemics, such as cholera epidemics in Berlin in the summer time, in order to throw some light on this matter. They found that no effect ascribable to temperature was visible in the course of such epidemics, as their progress was quite uninfluenced by meteorological conditions, the curves exhibiting a remarkable contrast to the infant mortality curves in the same city.

Again, McLaughlin (39) has shown that where a definite source of infection from gastro-intestinal diseases exists, as, for instance, a polluted water supply, the death rate in infants from enteritis may be nearly as great in the spring as in the summer months. This has been especially true of localities which have rather cool summers.

Flies.—Any hypothesis considering the summer deaths of infants as due to infections must clearly consider flies as probable or even principal carriers of the infecting organisms. The fly theory has been very carefully considered by O. H. Peters (50), who made an intensive study of the incidence of diarrhea in two sections inhabited by workmen of the city of Mansfield, England. He found no direct proof of the agency of flies in carrying summer diarrhea, and states that before this theory can be confirmed experiments of scientific accuracy will be required, such as were used to prove the transmission of yellow fever and malaria by mosquitoes. On the other hand, he could develop no data which would render the implication of flies in the transmission of gastro-enteritis inherently impossible.

The following chart drawn from the data given by Niven (48) shows the incidence of flies as compared with the deaths from summer diarrhea in Manchester, England, by weeks. The incidence of flies was determined by counting the numbers caught weekly in traps located in various parts of the city.

It will be seen that the death rate in infants lags behind the fly curve and then increases at a much more rapid rate than the flies. These increase in arithmetrical progression while the increase in infant deaths from diarrhea is almost geometrical. The impression derived from this curve is that of an increase in flies and summer diarrhea both due to a common cause.

One other difficulty is the circumstance that Peters found, that while 32 per cent of the breast-fed infants investigated developed an attack of diarrhea during their first year, 90 per cent of the infants fed on cow's milk were affected. Yet it is difficult to conceive of an affection, spread by flies, being selective in its nature in the same age group, especially as Peters found the proportion of breast-fed and bottle-fed children receiving table food to be approximately the same.

Besides this Peters found that the difference in the incidence noted above was dependent, not upon cow's milk per se but upon the circumstance of being breast-fed or not breast-fed. It can not be denied, however, that cow's milk, when kept uncovered in the home, is much exposed to infection by flies.

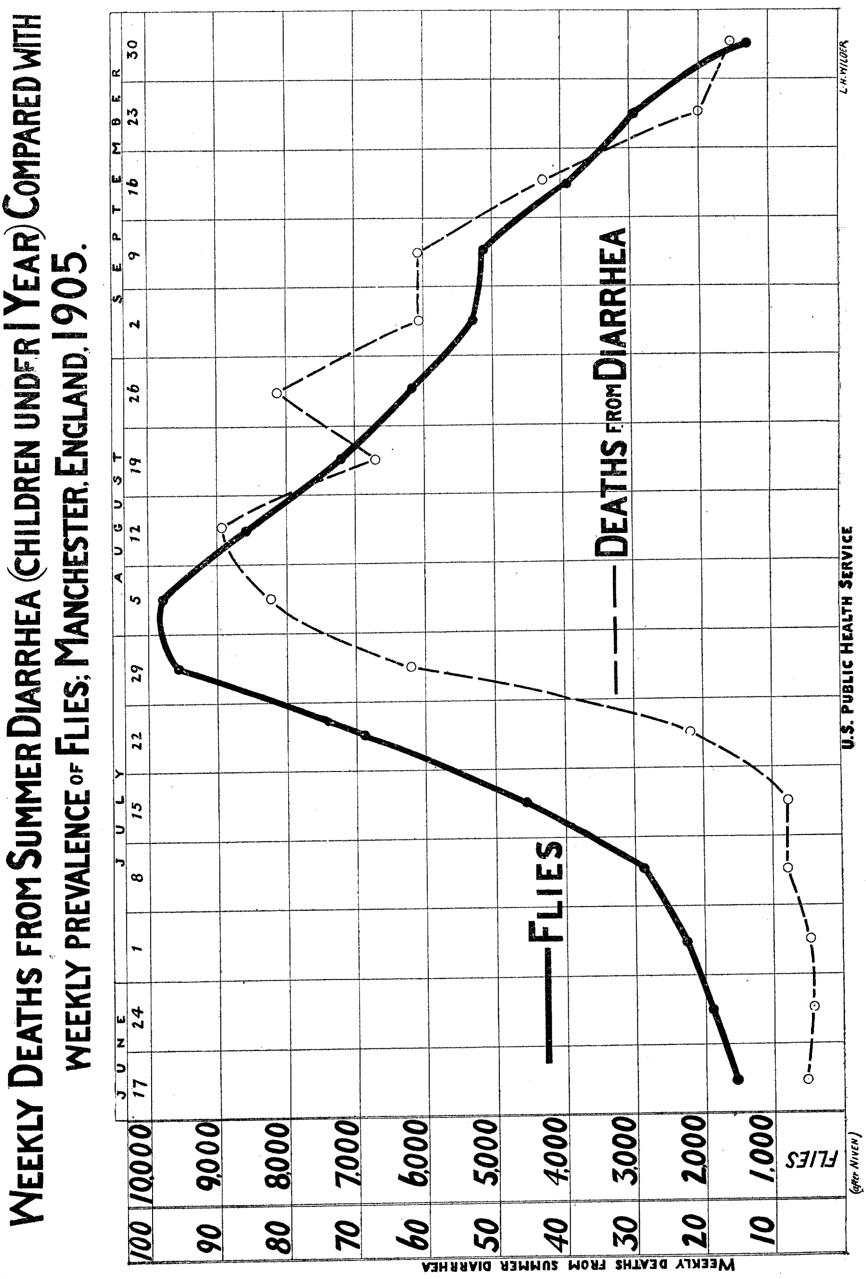
Finally Peters found that certain areas investigated had a much higher incidence of diarrhea than other sections showing a much greater prevalence of flies.

Effects of Heat upon Infants.

There remains now to examine the ways in which heat might damage the organism of the infant.

Heat stroke in infants.—We are all well aware that, every summer, numerous adults die in our great cities through heat stroke. As will be seen later there seem to be strong reasons for believing the infant more sensitive to heat than the adult, so there can be no ground for thinking that when adults perish, infants escape. It has been stated, in the foregoing, that hot days are accompanied by a number of deaths of infants with acute symptoms not referable to the

CHART IV.


WEEKLY DEATHS FROM SUMMER DIARRHEA (CHILDREN UNDER 1 YEAR) COMPARED WITH WEEKLY PREVALENCE OF FLIES; MANCHESTER, ENGLAND, 1905.
JUNE
17
24
JULY
1
8
15
22
29
AUGUST
5
12
19
26
SEPTEMBER
2
9
16
23
30
FLIES
DEATHS FROM DIARRHEA
100
90
80
70
60
50
40
30
20
10
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
FLIES
(after Niven)
WEEKLY DEATHS FROM SUMMER DIARRHEA
U.S. PUBLIC HEALTH SERVICE
L.H. WILDER

gastrointestinal tract. It is probable that a goodly proportion of these are cases of heat stroke.

While references to heat stroke in infants, in the literature, are by no means numerous, a number of cases have been reported by Illoway (21), Zahorsky (68), Snow (60), Finkelstein (9), Neuman and Japha (according to Reitschel) Rietschel (56), Liefmann and Lindemann (37), L. F. Meyer (46), and others. They were often breast-fed infants, were usually in good health, but for the most part of the fat, pasty type. In most instances some prodromal symptoms of restlessness and fretting have been present, after which the baby was taken suddenly ill, often in the evening, with loss of consciousness, high fever, hot skin, running pulse, and convulsions. The urine, when examined, was found to contain casts and acetone (in one case sugar, Finkelstein). With prompt hydrotherapy cures have been effected in many instances, while in others rapid death has ensued.

But, after all, only a small percentage of infants die during the summer in this fashion. Illoway estimates their number at 2 or 3 per cent, Finkelstein at 6 or 7 per cent of the total infant deaths in the summer. These are simple guesses for which there is no statistical verification.

Besides thermic fever we have two other types of affections especially fatal to infants in hot weather, (*a*) typical cholera infantum, running a rapidly fatal course with watery diarrhea, vomiting, fever, frequently convulsions, and (*b*) the subacute diarrheas which may last for days or weeks before a fatal termination.

It will be well, at this point, to run over the principal effects which have been noted as to the action of heat upon the human body.

Tolerance of heat.—With respect to adults, Rubner (58) found that temperatures in excess of 24° centigrade and relative humidities of 80 per cent caused symptoms of heat retention to make their appearance in adults. The experiments of Flügge, Paul, Ercklentz, and Heymann (13) have already been referred to as to the effects of stagnant air in setting up symptoms of heat retention.

Haldane (15) found that moderate work at wet-bulb temperatures in excess of 25.5° C. (78° F.) was impracticable by reason of symptoms of heat retention.

Effects of heat upon metabolism.—With rising temperatures the heat eliminated from the body by means of radiation and convection becomes progressively less until a point is reached in which all the labor of heat elimination is performed by the evaporation of moisture. Ranke (53) points out that when the body has to choose between the quantity of food necessary for nutrition and that consistent with heat regulation, it is compelled to choose the latter in self-defense. As a consequence in hot weather the appetite is greatly reduced.

As a result of calorimetric measurements, Ranke found that, with mean temperatures of 25° C. the intake of food sank, in adults, to energy values, below those represented by the metabolism of the fasting, resting adult.

Another effect of heat is to depress the anabolic processes. Thus L. F. Meyer (46) found while the weekly gains in weight by the infants at the Berlin City Orphanage during the relatively cool months of July and August, 1910, were 590 and 600 grams respectively, in the very hot months of July and August, 1911, that these were but 290 and 350 grams.

Heat, sufficient to cause rises in the rectal temperature of the resting adult and other symptoms of heat retention has also the property of increasing the rate of metabolism. Sutton (61) found that in an adult exposed to relatively high temperatures (37° C.), in addition to the symptoms of heat retention, the respiratory exchange and the respiratory quotient were raised. He concludes that high temperatures accelerate the metabolism as heat does any simple chemical reaction. In this way a vicious circle is established.

Evaporation of moisture.—While it is a matter of common knowledge that heat greatly increases the amount of water evaporated by the body, there is interest in referring to the amount of this loss. Hunt (20) found that with high dry temperatures (wet bulb around 70° F.) and exercise, as much as 13½ liters of water were taken daily and the secretion of urine was then by no means free. In another series of observations he found that, in spite of frequent drinking, 16 hours were required to replace water evaporated from the body during a day's experiments in the hot room. In these latter experiments the hemoglobin index of the blood was the same before and after exposure to the heat. Therefore the source of the water evaporated was the tissues of the body.

Effect of heat upon the digestive secretions.—There is evidence to show that the activities of the digestive glands, especially the stomach, are depressed by heat. V. Salle (59) found from animal experimentation that exposures to moderately high temperatures—29° to 31° C. (84.2° to 87.8° F.)—had the effect of greatly diminishing not only the amount ot the gastric secretions but their acidity and digestive activity. In this way the stomach not only loses a portion of its power to act upon food, but from the diminished or absent acidity there is a corresponding loss in the antiseptic and antifermentative action of the gastric juice.

Effect of heat upon the resistance to bacteria.—The observations of Medowikow (40) show that exposure to heat has the effect of diminishing the resistance of young animals to bacteria in the intestinal tract. Medowikow exposed young rabbits to incubator temperature for 12 hours. He found at the close of the experiment that not only were the bacteria in the intestinal tract increased but that in nine cases out of ten *B. coli* was present in the spleen or in the liver.

Effects upon the infant organism.—Let us now examine in what way the results enumerated above can be interpreted with respect to infants.

Metabolism of the infant.—In the first place the metabolism of the infant is keyed to a much higher plane than that of the adult. According to Nieman (47) the respiratory exchange of the infant is higher than that of the resting adult and corresponds to that of the adult doing moderate work. The total metabolism of infants is about 100 calories per kilogram and from 50 to 90 calories are required exclusive of the amounts retained for the purposes of growth. This corresponds to the energy quotient of an adult doing fairly severe muscular work.

Another evidence of the more active metabolism of the infant is shown by the skin temperature. Rubner (58) found that a thermometer placed between the skin of an adult's chest and a woolen undershirt registered about 32° C. Liefmann and Lindemann (37) state that thermometers inserted between the skin and clothing of infants registered between 34° and 35° C.

Since the metabolism of infants is higher, they produce much more heat than the adult in proportion to their weight. Though it is true that they have also a proportionately greater skin surface to provide for the elimination of this increased amount of heat, it must follow that when the escape of heat is prevented by meteorological conditions their greater rate of metabolism must favor heat retention.

Thermo regulation in the infant.—We can deduce from the above for the infant narrower temperature limits within which heat regulation is efficient than for adults, and consequently a more labile condition of temperature equilibrium. Experimentally such has proven to be the case. The observations of Generisch (14), Rietschel (57), Kleinschmidt (27), Heim and John (17), show that when infants are experimentally exposed to moderately high heat (28° to 32° C.) a rise in their body temperatures takes place. This rise was found to be greater in infants suffering from disturbances of the nutrition (Kleinschmidt, Rietschel).

Meinert (41) in his investigations in Dresden found that the rectal temperatures of infants in homes where the indoor temperatures were high were increased to 39° or 40° C., although according to the parents' statements the infants had been comparatively well.

Reduction of tolerance for food.—Another effect of heat is the reduction of the tolerance for food. Ranke's observations in respect to this effect of heat upon adults have already been mentioned. The adult, however, taking both solids and liquids, can diminish the one and increase the other.

Meinert (41) points out that in the breast-fed infant this demand for increased liquids is regulated by the breast, for as a result of numerous observations he has found that breast milk is more fluid in the summer than in the winter. Indeed this is to be expected, as in hot weather the mother will instinctively drink more and eat less.

Besides this, v. Pirquet (51) also points out that not only the quantity but the quality of the food obtained by the breast-fed child is influenced by its appetite. In hot weather, when this is reduced, it quickly ceases to suck, hence it receives only the more fluid "foremilk," while the rich "aftermilk" remains in the breast.

The bottle-fed child is far more passive in this respect to its food, which it obtains with a minimum effort through the effects of gravity. It therefore varies its intake far less than the breast-fed child. Moreover, its increased thirst often leads mothers to satisfy it with additional food instead of water.

It is obvious under these conditions that bottle-fed babies are often relatively overfed in hot weather, a circumstance commented on by numerous authors.

Another effect of heat of importance to the digestion of infants is the diminution of the quantity, acidity, and activity of the gastric juice, as shown by Salle's experiments and the resistance of the intestinal tract to bacteria as demonstrated by Medowikow.

Not only will the digestive processes take place with greater slowness, thus favoring stagnation of the intestinal contents, but the deficient acidity of the gastric juice may doubtless permit pathogenic germs which would otherwise succumb to its acidity to gain access to the intestine. The diminished resistance of the intestine to bacteria would permit the proliferation of germs introduced in this manner or favor endogenous infections.

We see from the foregoing that there are a number of reasons why heat should exercise a particularly deleterious influence on infants. There remain for final examination the possible effects of heat in respect to cholera infantum and the subacute intestinal infections.

Effect of Heat in Producing Cholera Infantum.

Typical cholera infantum has always been regarded by the earlier American authors (cf. Miller) as a heat effect. The following reasons have been advanced by Meinert, Rietschel, and others for regarding it from this standpoint:

1. The severe form makes its appearance only after exposure to very hot weather or high indoor temperatures.

2. It often attacks infants hitherto in the best of health. Meinert found that 54 per cent of all the infants whose deaths he investigated had always enjoyed good health, while Johnston (24), from his observations in Leicester, places this at 75 per cent.

3. The bacteriological findings and post-mortem appearances in cholera infantum are far more indefinite than in the subacute intestinal affections.

4. High fever is usually present.

5. A heat effect may be inferred *ex juvantibus*, or, in other words, the most effective treatment is removal to a cool location, hydrotherapy, and restoration of the body fluids.

In this connection a case recited by Rietschel (56) is instructive. During the summer of 1911 an artificially fed infant, receiving excellent milk, both from a quantitative and qualitative standpoint from the Dresden Säuglingsheim, lived in a dwelling where continuously high temperatures were registered. The infant bore the heat very well up to the 8th of August. No diarrhea was present up to that time, the bowels being somewhat constipated. On that date slight diarrhea made its appearance, but the child, while listless, seemed comfortable. On the 9th the symptoms suddenly changed. The diarrhea became spurting and the child's temperature rose to 40 C. The infant was quickly removed to the hospital, where the fever was reduced by hydrotherapy. We are not informed as to the subsequent fate of the child.

Subacute diarrhea.—While in this class of affections the influence of heat is by no means so apparent, from the statements already made, however, it must be conceded that heat has important predisposing effects in the following ways:

1. By reduction of the tolerance for food.
2. By reduction of the activity of the digestive secretions.
3. By reduction of the normal resistance of the intestines to bacterial invasions.

Clinical experience has shown that stormy symptoms can be induced by feeding infants excessive amounts of the purest food from the bacteriological standpoint. The relative reduction of the tolerance for food by the action of heat must, as has already been pointed out, produce many instances of overfeeding, leading to nutritional disturbances.

The continued influence of heat upon the infant, whose nutrition has been thus disturbed, leads to disturbances of the thermal regulation which has been found to be more labile in children with digestive disturbances.

This in turn has the effect of still further lowering the tolerance, so that in this way a vicious circle is established. Added to this are the weakness of the digestive secretions, the stagnation of food in the intestine, and increased susceptibility to exogenous and endogenous infections.

It seems clear, from the foregoing, that we must regard heat as a powerful factor in directly determining the summer mortality of infants. Yet to ascribe all of summer mortality directly to this cause would be as one-sided as to ascribe it all to the method of feeding.

I think, however, that the recent observations recorded have furnished us with lines of much greater precision on which to base our preventive measures. Our attention has, besides, been especially directed anew to the influence of poor housing conditions in the production of summer deaths in babies.

The indications for prophylaxis are plain. They consist, hand in hand with an improvement in housing conditions and the development of residential suburbs, in a greater emphasis upon the care of infants in their homes in the summer months. Mothers must also be informed of the fact that excessive heat, per se, is deleterious to infants and, when hot weather is present, special efforts must be made to prevent overheating and relative overfeeding of babies by the use of frequent tepid baths, light clothing, fresh air, increase in the amount of water given, lengthening of the feeding intervals, and reduction in the amounts of food. The advantages of breast-feeding are only emphasized by all that has been brought out. Here nature automatically modifies the composition of a food in accordance with the heat in a way to which artificial feeding can never compare.

Conclusions.

1. The action of heat as a direct cause in the summer mortality of infants has been greatly underestimated in the last 25 years. In the future much more weight should be given to its influence.
2. The lethal action of heat is a function, not so much of the maximum and mean temperatures of the external air as of the indoor temperatures, which, in the late summer, may continue to be high, in spite of remissions in temperature of the external air.
3. The action of dirty and stale milk in causing the death of infants has been given a significance which has overshadowed other factors of equal or greater importance.
4. There is evidence to show that a certain proportion of infant deaths are due to specific infections, in the dissemination of which contact infection and flies doubtless play a part.
5. As a result, future activities for the prevention of infant mortality must concentrâte themselves to a greater extent on the question of housing, especially the conditions productive of high indoor temperatures, such as overcrowding, narrow streets, and the absence of through ventilation.
6. Poor housing conditions can be partially neutralized by the proper care of babies in the summer. The general public should be educated as to the importance of high indoor temperature in caus-

ing the death of infants, and especially as to measures which prevent babies from suffering from the heat.

7. Breast feeding must still be regarded as a most, if not the most, important preventive of the summer death of infants.

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